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CHEM 200 & Chem 202 Course Information – Spring 2012

Instructors:

Prof. L. Beauvais, Chem200@sciences.sdsu.edu
Office Hours: to be posted on Chem 200 website

Laboratory Coordinator:

Prof. D. Chatfield, Phone: 594-4843, Chem200@sciences.sdsu.edu
Office Hours (in GMCS-213A): to be posted on Chem 200 website

Texts:

Chemistry: The Molecular Nature of Matter and Change, 5th Ed., Silberberg ISBN 0077216504 (Required)
Student Solutions Manual for Chemistry, 5th Ed. Wiegand and Samberg ISBN 0073048607 (Optional)

On-Line Homework:

ARIS Access Card to Accompany Silberberg, 5th Ed. ISBN 0077256433 (Required)

Class Participation:

I – clicker system

CHEM 200 & Chem 202 Information:

Important course information (handouts, answer keys, announcements) will be posted on the CHEM 200 website (<http://www.chemistry.sdsu.edu/courses/CHEM200>). You must *regularly* check this site during the semester. The majority of information listed for Chem 200 students also applies to Chem 202 students. Exceptions are noted in this document and in Appendixes, A and B.

GRADES:

Your grade for CHEM 200 will be determined by the number of points you earn on the following assessments:

3 Hour Exams (150 each)	450
10 Quizzes (10 each, drop lowest score)	90
Conductivity Demonstration	10
12 Lab Reports (20 each, drop lowest score)	220
Ch. 1 & 2 Assignment	10
Lab Practical Exam	40
On-Line Homework	50
Class Participation	50
Final Exam	250
Total Points	<u>1170</u>

Individual grades for assignments and exams will be posted on Blackboard (<http://blackboard.sdsu.edu/>) throughout the semester. Letter grades will be assigned using the absolute scale shown below (divide your score by the total points given above). Chem 202 students will have their grade calculated according to the guidelines shown in Appendix A.

A	> 90 %	C+	68 – 72 %
A–	85 – 90 %	C	63 – 68 %
B+	81 – 85 %	C–	59 – 63 %
B	76 – 81 %	D	53 – 59 %
B–	72 – 76 %	F	< 53 %

Please note that because this class is *not* curved, your grade *cannot* be adversely affected by the performance of others. A grade record sheet to help you track your progress during the course is included on page 12. Chem 202 students will find a grade record sheet in Appendix B.

Please bring all questions and concerns about grading and operation of the labs to the lab coordinator. The instructors will write the exams, quizzes, and exam keys, but they are not responsible for the lab grading itself or the conduct of the labs.

ENROLLMENT/CRASHING POLICY:

Enrolled Students. Enrollment in CHEM 200 & 202 is contingent upon being enrolled in a laboratory section for the course. Laboratory section enrollments will be finalized by the end of the 3rd meeting of the scheduled lab (see below). Therefore, *it is absolutely crucial that you attend the first three laboratory periods*. Failure to do so may result in your spot in the laboratory section being given to another student. Notify the laboratory coordinator (by email - before the first week of class) if you must miss a laboratory period in the first week of the semester for some legitimate reason. You must be able to attend the laboratory section of CHEM 200 for which you are enrolled; otherwise, you must drop the course and attempt to crash a different section that you can attend (see below). If you decide to drop the course, inform the laboratory coordinator by email as soon as possible (Chem200@sciences.sdsu.edu) so your place can be given to a crasher.

Crashers. If you are attempting to crash CHEM 200, you must attend the lab section in which you wish to enroll in for the first three scheduled lab meetings of the semester. You must have passed the Placement Test given by the Placement Testing Office to retain a spot on the crashers list. Available spots will be filled as they open up during the first week of lab, but add codes for the course will not be given out until the end of the second week: Add codes for the course will *not* be given out in lecture, so please don't ask. Please bring questions about enrollment to the lab coordinator (room GMCS-213A, Chem200@sciences.sdsu.edu).

ATTENDANCE POLICY:

Regular attendance in the lectures is *strongly* recommended, and class participation will be measured using clickers. Detailed information will be discussed in lecture. If you do have to miss class, you should obtain class notes from another student.

Attendance in all laboratory meetings is **REQUIRED**, and all lab work during the semester must be done in the scheduled laboratory periods. Note that Chem 202 students are required to attend only the laboratory and not the discussion section lab per week. *Under no circumstances will students be allowed to make up lab experiments or quizzes that are missed.* You will receive zero points for the assignments, quizzes and labs that you miss. You should still inform your TA (and submit a note or official form from a responsible party) if you must miss a laboratory meeting or discussion for legitimate reasons (illness, scheduled events, court appearances, etc.). This will allow us to take your absence into consideration when determining your grade. PLEASE consult your TA and/or the laboratory coordinator for ANY reasons that you need to miss a Lab - your forthright communication is important to ensure your success! If you are repeating either the Chem 200 or Chem 202 lab, no previously written lab reports will be allowed for this current semester - in other words, "dry labs" will receive a grade of zero. You MUST be present and conduct ALL of your experiments professionally in each and every lab period - absolutely no exceptions to this ethical and professional standard of conduct! Because you are allowed to consult with your colleagues during and following all of your laboratory experiments (except during the Lab Practical Exam), you have ample opportunity to create stellar, professional lab reports worthy of high scores and scientific merit - we expect the VERY BEST from YOU always, as YOU ARE ALL CAPABLE OF CONDUCTING AND PREPARING OUTSTANDING LABORATORY EXPERIMENTS AND REPORTS!

COURSE CONTENT:

The course content for CHEM 200 will correspond roughly to the material covered in Chapters 1–13 in the Silberberg text. This material will be covered in order. The first and second chapter, we review and *will not be covered in detail in lecture*, but Ch. 1 & 2 Assignment will give you practice on the principles covered. See the course outline on page 9-11 for a comprehensive breakdown of the specific topics that will comprise the course content.

QUIZZES:

Ten quizzes will be given in the discussion section on the dates indicated in the course outline (see page 9-11). The specific content for each quiz will be announced in lecture. The quizzes will be given during the last 15 minutes of discussion and will be worth 10 points each. There will be multiple versions of each quiz, and all versions (with keys) will be made available to the students on the CHEM 200 website for study once everyone has taken the quiz. ***There will be no regular make-up quizzes.***

EXAMS:

The date, time, and chapters covered for the exams in CHEM 200 are listed in the table below. Note that the final exam will be *comprehensive* and may also include material from Chapters 12 and 13 not in the previous hourly exams.

Exam	Date and Time	Text Material Covered
Exam 1	Friday, February 17, 2:00-3:40 PM	Chapters 1–5
Exam 2	Friday, March 16, 2:00-3:40 PM	Chapters 6–8
Exam 3	Friday, April 20, 2:00-3:40 PM	Chapters 9–11
Final	Saturday, May 12, 6:00-8:00 PM	Comprehensive
Lab Practical	Mon/Tues (in lab) April 30 & May 1	Laboratory Work

The lecture exams will consist of multiple-choice questions and be worth 150 points (Exams 1-3) or 250 points (Final Exam). All questions will be answered BOTH on a Scantron sheet and directly on the exam. For each exam, you will be provided with a periodic table (page 14) and an information sheet (page 15) containing various physical constants, conversion factors, and equations. Exam re-grades will be considered only during the week following each exam. The Lab Practical exam is given during the regularly scheduled lab periods.

In general, there will be no make up exams. If you have a valid reason that precludes you from taking an exam at the regularly scheduled times, contact the laboratory coordinator ***two weeks*** before the exam. If you have a valid reason for missing an exam and absolutely can not make other arrangements, a “make-up” exam *may* be scheduled.

A *laboratory practical exam* will be given during regular laboratory periods (see schedule above), and will assess how well you mastered the laboratory skills associated with the course. The Lab Practical Exam is worth 40 points and *cannot be skipped*. More information on the specific experiments covered in the lab practical exam will be provided later in the semester, but they are all based on experiments from earlier in the semester.

LABORATORY REPORTS:

There are 12 laboratory experiments, each worth 20 points, associated with the laboratory portion of the course. For each laboratory experiment day, you will perform your laboratory experiments and procedures on that day, record all necessary laboratory measurements and experimental data during your lab, and turn in your completed laboratory report (the pages from this laboratory notebook) for grading. Because of logistical constraints (each lab requires specific reagents, materials, and equipment prepared in advance, and the preparation of your TA), you will not normally be allowed to make up missed lab experiments; exceptions are at the discretion of the laboratory coordinator. See the Introduction to Laboratory Work in the manual for more information on preparing laboratory reports.

Each of your laboratory experiments lists the point distribution for each experiment. There should be no confusion regarding how to earn your points and how these points are distributed in your experiments. Your lab TA is responsible for helping you to succeed in the lab and your TA will determine the grades for each of your laboratory experiments. If you feel that you are not receiving the help that you need, please inform the laboratory coordinator immediately so that he can remedy any problem and so that YOU can perform well in your laboratory experiments. If you work hard and attend all of your labs, there is no reason that you cannot earn most of your assigned laboratory points.

ATTENDANCE IS ABSOLUTELY MANDATORY for all laboratory experiments. We are encouraging you to attend all of your labs and to PLEASE submit all of your laboratory reports with a sincere effort to excel. YOU are the future scientists of our world, and we know that YOU are capable of great success!

HOMEWORK PROBLEMS:

An *essential* part of studying for the exams and quizzes is attempting to solve homework problems included in the text. Homework problems will be assigned using ARIS, the on-line homework system designed to accompany your textbook. It will also be of benefit to you to work end-of-chapter problems in the textbook.

CLASS PARTICIPATION:

Each student must purchase the I-clicker system. This will allow students to answer questions during class. There will be two to four questions per lecture beginning with the second lecture on September 1. These questions are presented in multiple choice format and the student typically has 1 - 2 minutes to respond using the Clicker. A histogram of responses is displayed at the end of each exercise. The purpose of this exercise is to identify any misunderstandings with the material and encourage active learning.

A maximum of 50 grade points can be earned from *class participation*. Each student receives one *clicker point* for each question answered correctly and one *clicker point* for attempting all of the questions in a lecture. At the end of the semester, a student's *clicker points* are added and then increased by 20% to allow for absences, malfunctioning clickers, and all other possible problems. These *clicker points* are then normalized to the maximum of 50 *grade points*. For example, if there are 100 possible *clicker points* in a semester and a student earns 50 *clicker points*, the student will receive a total of 30 *grade points* after the 20% increase.

It is your responsibility to have a functioning and fully registered device. The clicker points collected during the first few weeks of class will serve as a test period to deal with any clicker bugs. Starting on

February 6, the clicker points will be used for grading purposes. If you have clicker problems, please contact the SDSU clicker support team at <http://clicker.sdsu.edu>.

HELP ROOM FOR CHEM 200:

There will be a CHEM 200 Helproom in GMCS-212 for students seeking outside consultation and assistance on the course material. The Helproom will be staffed by the teaching assistants and the instructors (during their office hours) and will be open approximately 20 hours per week. The Helproom schedule will be posted on the CHEM 200 website and on the door of the Helproom at the beginning of the second week of class.

AM I READY FOR CHEM 200?

ASSUME THIS CLASS WILL REQUIRE A MINIMUM OF 15 HOURS OF YOUR TIME PER WEEK TO COMPLETE!

The prerequisites for CHEM 200 are one year of high school chemistry, two years of algebra, and a passing score on the Placement Test, or a passing grade (a C or higher) in Chem 100. Chemistry 200 is a demanding, 5-unit course which requires an enormous amount of time and your commitment to work hard! (Please do NOT take this course unless you are prepared to commit the necessary time and hard work.) It is advisable that you make Chemistry 200 the focus of your semester and that you do NOT overburden yourself with an unmanageable course load while taking this course. YOUR success is our success, and we want you to succeed in this course. YOUR success requires a large time commitment and hard work – please do NOT take this course unless you are willing to allow sufficient time to study, attend ALL lectures, and attend ALL labs with preparation in advance. Writing good laboratory reports also requires a lot of time and preparation prior to lab. You will enjoy your semester in Chemistry 200 – and you will benefit in the sciences so much more from all that you learn – if you allow yourself the time necessary to work hard and succeed! PLEASE ALLOW ADEQUATE TIME IF YOU TAKE THIS COURSE!

STATEMENT ON PLAGIARISM AND ACADEMIC HONESTY

Academic dishonesty includes cheating, plagiarism, and related activities that are intended to gain unfair academic advantage. Please familiarize yourself with the University policy on Academic Honesty at <http://senate.sdsu.edu/policy/pfacademics.html>. All suspected cases of academic dishonesty will be investigated and class actions will be taken, including assignment grade modification and course grade reduction. Furthermore, cases will be referred to the Center for Student Rights and Responsibilities for further action.

LIST OF LABORATORY EXPERIMENTS AND IN-LAB ASSIGNMENT

These experiments are included in this laboratory manual starting on page 41.

- Experiment 1. Measurement of Mass and Density
 - Experiment 2. Measuring Avogadro's Constant Using Simple Lab Equipment
 - Experiment 3. Decomposition of Potassium Chlorate
 - Experiment 4. Calorimetry, Part I: Specific Heat Capacity
 - Experiment 5. Calorimetry, Part II: Enthalpy of Reaction
 - Experiment 6. Emission Spectra of Hydrogen and Helium
 - Experiment 7. Qualitative Analysis
 - Experiment 8. The pH of Ordinary Chemicals
 - Experiment 9. Analysis of an Alloy, part I
 - Experiment 10. Analysis of an Alloy, part II
 - Experiment 11. Standardization of a NaOH Solution
 - Experiment 12. Molar Mass of an Unknown Acid
- Chapter 1 & 2 Review: Review of Scientific Measurement and Atomic Structure
- In-Lab Demonstration 1: Worksheet for Conductivity of Solutions

CHEM 200 & CHEM 202* Course Outline

Spring 2012

Date	Lecture Monday	Laboratory Monday/Tuesday	Lecture Wednesday	Discussion* Wednesday/Thursday	Lecture Friday
Week #1 Jan 16 - 20		No Lab Meeting	First day of lecture Introduction Ch. 1	Ch. 1 & 2 Review (p. 194)	Chemical Nomenclature Stoichiometry Ch. 2 & 3
Week #2 Jan 23 - 27	Limiting Reactants Percent Yield Ch. 3	Safety Discussion Exp. 1	Chemical Reactions Ch. 4	Quiz 1	Chemical Reactions Ch. 4
Week #3 Jan 30- Feb 3	Chemical Reactions Ch. 4	Conductivity Demo (last day to drop classes)	Gas Laws & Kinetic Molecular Theory Ch. 4 & 5	Quiz 2 (last day to add classes)	Gas Laws & Kinetic Molecular Theory Ch. 5
Week #4 Feb 6 - 10	Gas Laws & Kinetic Molecular Theory Ch. 5	Exp. 3: Decomposition of $KClO_3$	Gas Laws & Kinetic Molecular Theory Ch. 5	Quiz 3	Thermochemistry Ch. 5 & 6
Week #5 Feb 13 - 17	Thermochemistry Ch. 6	Exp 4: Calorimetry Part 1	Thermochemistry Ch. 6	Exam Review	Exam 1 2:00 PM – 3:40 PM
Week #6 Feb 20 - 24	Thermochemistry Ch. 6	Exp 5: Calorimetry Part 2 Exam 1 Returned	Thermochemistry Quantum Theory Ch. 6 & 7	Quiz 4	Quantum Theory & Atomic Structure Ch. 7

* Chem 202 students do not attend discussion sections.

CHEM 200 & CHEM 202* Course Outline (cont)

Spring 2012

Date	Lecture Monday	Laboratory Monday/Tuesday	Lecture Wednesday	Discussion* Wednesday/Thursday	Lecture Friday
Week #7 Feb 27 - Mar 2	Quantum Theory & Atomic Structure Ch. 7	Exp 6: Emission Spectra	Quantum Theory & Atomic Structure Ch. 7	Quiz 5	Electron Configuration Chemical Periodicity Ch. 8
Week #8 Mar 5 - 9	Electron Configuration Chemical Periodicity Ch. 8	Exp 7: Qualitative Analysis	Electron Configuration Chemical Periodicity Ch. 8	Quiz 6	Electron Configuration Chemical Periodicity Ch. 8
Week #9 Mar 12 - 16	Models of Chemical Bonding Ch. 9	Exp 8: pH	Models of Chemical Bonding Ch. 9	Exam Review	Exam 2 2:00 PM – 3:40 PM
Week #10 Mar 19 - 23	Models of Chemical Bonding Ch. 9	Exp 12: Avagadro's Number Exam #2 Returned	Shapes of Molecules Ch. 10	Quiz 7	Shapes of Molecules Ch. 10
Week #11 Mar 26 - 30		SPRING RECESS		SPRING RECESS	
Week #12 Apr 2 - 6	Shapes of Molecules Ch. 10	Exp. 9: Analysis of an Alloy, Part 1	Theories of Covalent Bonding Ch. 10 & 11	Quiz 8	Theories of Covalent Bonding Ch. 11

* Chem 202 students do not attend discussion sections.

CHEM 200 & CHEM 202* Course Outline (cont)

Spring 2012

Date	Lecture Monday	Laboratory Monday/Tuesday	Lecture Wednesday	Discussion* Wednesday/Thursday	Lecture Friday
Week #13 Apr 9 - 13	Theories of Covalent Bonding Ch. 11	Exp 10: Analysis of an Alloy, Part 2	Theories of Covalent Bonding Ch. 11	Quiz 9	Theories of Covalent Bonding Ch. 11
Week #14 Apr 16 - 20	Intermolecular Forces Ch. 11 & 12	Exp 11: Standardization of NaOH	Intermolecular Forces Ch. 12	Exam Review	Exam 3 2:00 PM – 3:40 PM
Week #15 Apr 23 - 27	Intermolecular Forces Ch. 12	Exp. 12: Molar Mass of an Unknown Acid Exam #3 Returned	Intermolecular Forces Ch. 12	Quiz 10	Intermolecular Forces Ch. 12
Week #16 Apr 30 - May 4	Properties of Mixtures Ch. 12 & 13	Lab Practical Exam	Properties of Mixtures Ch. 13	Exam Review	Properties of Mixtures Ch. 13
Week #17 May 7 - 11 -	Properties of Mixtures Ch. 13	Locker Checkout	Properties of Mixtures Ch. 13 Last day of classes	NO LAB	

* Chem 202 students do not attend discussion sections.

Final Exam: Saturday, May 12, 6 pm-8 pm

CHEM 200 Grade Record Sheet – Spring 2012

Use this page to record your grades and track your progress in the course.

EXAMS:

	Exam 1	Exam 2	Exam 3	Lab Practical	Final Exam
Score					
Max	150	150	150	40	250

EXPERIMENTS:

	1	2	3	4	5	6	7
Score							
Max	20	20	20	20	20	20	20
	8	9	10	11	12		
Score							
Max	20	20	20	20	20		

QUIZZES:

	Conductivity Demo	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10
Score											
Max	10	10	10	10	10	10	10	10	10	10	10

EXAM REVIEWS AND IN-LAB ASSIGNMENTS:

Chapter 1 & 2	On-Line Homework	Class Participation	Safety Quiz
10	50	50	10

Sample Exam Cover Sheet

CHEM 200 Exam 1

October 2nd, 2008

Name _____ Lab Sect. No. _____
(Print) Last First

Signature _____
(Signature here)

This exam consists of 31 questions at 5 points each for questions 2-31, and one point for Question 1 for a total of 151 points. Make sure that your test has all 11 pages (including this cover sheet). *Please read each problem carefully. There are no intentionally misleading questions; each problem should be taken at its face value.* Please mark your answers ***on the Scantron sheet*** provided to you ***and on the actual exam.***

You will be given a periodic table and an exam information sheet to use during the exam. You may remove it from the exam make it more accessible. You may also use the designated Casio fx-300ms-plus calculator or equivalent non-programmable non-graphing scientific calculator during the exam. Use the back pages of the test as scratch paper. You are not allowed to use any textbooks, notes, or homemade reference sheets during the exam.

You may leave if you finish the exam early. Give the exam and the information sheet to your TA and leave quietly without disturbing other students. Before leaving, check that all your answers have been properly entered on the Scantron sheet and the exam and that your name is written on every page of the exam and on the Scantron sheet.

All cell phones and electronic devices must be turned off and put away. Please remove all hats and caps. Place your books and all papers out of sight under your seat. If the TA believes that you might be looking at your neighbors' paper, you will be asked to move to a new location.

Exam scores will be posted on Blackboard as soon as the grading is complete. Your test will be returned to you in the first lab meeting of next week. If you have any questions regarding the grading of your exam, please notify your TA.

The time available for the exam is 100 minutes. **Good luck!**

Periodic Table of the Elements

18

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	
1 H 1.008	2 He 4.003	3 Li 6.941	4 Be 9.012	5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18	11 Na 22.99	12 Mg 24.31	13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.07	17 Cl 35.45	18 Ar 39.95	
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.87	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.64	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80	
37 Rb 85.47	38 Sr 87.62	39 Y 88.91	40 Zr 91.22	41 Nb 92.91	42 Mo 95.94	43 Tc [98]	44 Ru 101.1	45 Rh 102.9	46 Pd 106.4	47 Ag 107.9	48 Cd 112.4	49 In 114.8	50 Sn 118.7	51 Sb 121.8	52 Te 127.6	53 I 126.9	54 Xe 131.3	
55 Cs 132.9	56 Ba 137.3	57-70 *	71 Lu 175.0	72 Hf 178.5	73 Ta 180.9	74 W 183.8	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.1	79 Au 197.0	80 Hg 200.6	81 Tl 204.4	82 Pb 207.2	83 Bi 209.0	84 Po [209]	85 At [210]	86 Rn [220]
87 Fr [223]	88 Ra [226]	89-102 **	103 Lr [262]	104 Rf [261]	105 Db [262]	106 Sg [266]	107 Bh [264]	108 Hs [277]	109 Mt [268]	110 Uu [289]	111 Uub [288]	112 Uuq [294]	113 Uuq [294]	114 Uuq [294]	115 Uuq [294]	116 Uuq [294]	117 Uuq [294]	118 Uuq [294]

Metals

Non
Metals

* Lanthanoids	57 La 138.9	58 Ce 140.1	59 Pr 140.9	60 Nd 144.2	61 Pm [145]	62 Sm 150.4	63 Eu 152.0	64 Gd 157.3	65 Tb 158.9	66 Dy 162.5	67 Ho 164.9	68 Er 167.3	69 Tm 168.9	70 Yb 173.0
** Actinoids	89 Ac [227]	90 Th 232.0	91 Pa 231.0	92 U 238.0	93 Np [237]	94 Pu [244]	95 Am [243]	96 Cm [247]	97 Bk [247]	98 Cf [251]	99 Es [252]	100 Fm [257]	101 Md [258]	102 No [259]

CHEM 200 Exam/Quiz Information Sheet – Spring 2012

Physical Quantities

atomic mass unit (amu) = 1.66056×10^{-27} kg

Avogadro's number = 6.022×10^{23}

universal gas constant (R) = 8.314 J/K•mol = 0.08206 L•atm/K•mol

absolute zero = -273.15 °C = 0 K

specific heat capacity of water ($c_{\text{H}_2\text{O}}$) = 4.184 J/g•K

speed of light (c) = 3.000×10^8 m/s

Planck's constant (h) = 6.626×10^{-34} J•s

Conversion Factors

1 angstrom (Å) = 10^{-10} m

1 atm = 1.01325×10^5 Pa = 1.01325 bar = 760 Torr

1 calorie = 4.184 J

1 joule = 1 kg•m²/s²

Equations

$$PV = nRT$$

$$P_A = X_A \times P_{\text{total}}$$

$$d = \frac{(\text{molar mass}) \times P}{RT}$$

$$u_{\text{rms}} = \sqrt{\frac{3RT}{(\text{molar mass})}}$$

$$\Delta E = q + w$$

$$\Delta H_{\text{rxn}} = \sum \Delta H_f^\circ(\text{products}) - \sum \Delta H_f^\circ(\text{reactants})$$

$$\text{heat capacity} = q/\Delta T$$

$$\text{specific heat capacity } (c) = q/(\text{mass} \times \Delta T)$$

$$\text{speed of light } (c) = \nu \times \lambda$$

$$E_{\text{photon}} = h\nu = \frac{hc}{\lambda}$$

$$E_{\text{electron}} = -2.18 \times 10^{-18} \text{ J} \left(\frac{Z^2}{n^2} \right)$$

$$\lambda = \frac{h}{mu}$$

$$\frac{1}{\lambda} = 1.096776 \times 10^7 \text{ m}^{-1} \left(\frac{1}{n_1^2} - \frac{1}{n_2^2} \right), \text{ where } n_2 > n_1$$

Common Ionic Species in Aqueous Solution

You need to memorize the names and formulas for the cations and anions on this page for ALL your quizzes and exams

Cations (positive ions)

Anions (negative ions)

<u>Name</u>	<u>Formula</u>	<u>Name</u>	<u>Formula</u>
hydronium ion	$[\text{H}_3\text{O}]^+$	fluoride	F^-
ammonium ion	$[\text{NH}_4]^+$	chloride	Cl^-
lithium ion	Li^+	bromide	Br^-
sodium ion	Na^+	iodide	I^-
potassium ion	K^+	oxide	O^{2-}
magnesium ion	Mg^{2+}	sulfide	S^{2-}
calcium ion	Ca^{2+}	nitride	N^{3-}
barium ion	Ba^{2+}	hydroxide	OH^-
chromium(II) ion	Cr^{2+}	cyanide	$[\text{CN}]^-$
chromium(III) ion	Cr^{3+}	hypochlorite	$[\text{ClO}]^-$
manganese(II) ion	Mn^{2+}	chlorite	$[\text{ClO}_2]^-$
manganese (IV) ion	Mn^{4+}	chlorate	$[\text{ClO}_3]^-$
iron(II) ion	Fe^{2+}	perchlorate	$[\text{ClO}_4]^-$
iron(III) ion	Fe^{3+}	sulfite	$[\text{SO}_3]^{2-}$
cobalt(II) ion	Co^{2+}	sulfate	$[\text{SO}_4]^{2-}$
cobalt(III) ion	Co^{3+}	hydrogen sulfate	$[\text{HSO}_4]^-$
nickel(II) ion	Ni^{2+}	(or bisulfate)	
copper(I) ion	Cu^+	nitrite	$[\text{NO}_2]^-$
copper(II) ion	Cu^{2+}	nitrate	$[\text{NO}_3]^-$
silver ion	Ag^+	phosphate	$[\text{PO}_4]^{3-}$
zinc ion	Zn^{2+}	hydrogen phosphate	$[\text{HPO}_4]^{2-}$
cadmium ion	Cd^{2+}	dihydrogen phosphate	$[\text{H}_2\text{PO}_4]^-$
mercury(II) ion	Hg^{2+}	carbonate	$[\text{CO}_3]^{2-}$
aluminum ion	Al^{3+}	hydrogen carbonate	$[\text{HCO}_3]^-$
tin(II) ion	Sn^{2+}	(or bicarbonate)	
tin(IV) ion	Sn^{4+}	acetate	$[\text{CH}_3\text{CO}_2]^-$
lead(II) ion	Pb^{2+}	permanganate	$[\text{MnO}_4]^-$
		molybdate	$[\text{MoO}_4]^{2-}$

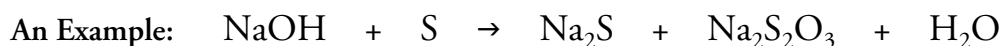
Balancing Chemical Equations

Helpful reminders:

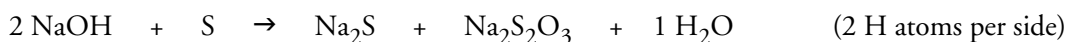
- Coefficients operate on **all** atoms in the chemical formula that follow it.
- When balancing an equation, do not alter the chemical formulas or add additional reactants or products, as this changes the chemical reaction.

Method for balancing equations by inspection:

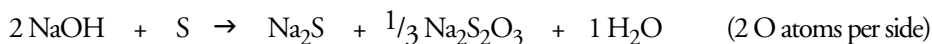
1. Identify those kinds of atoms that occur in only one substance on each side of the equation.
2. If the number of identified atoms (from step 1) is greater than one, choose those that are present in compounds only (not as elements).
3. If there is still a choice of atoms (from steps 1 and 2), select the one that is a component of the most complicated compound (most atoms or kinds of atoms) in the equation.
4. Balance the equation first for the selected atom.
5. Continue the process by next balancing the equation in the other atoms that are components of one unbalanced substance only.



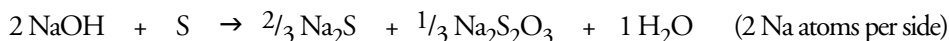
Hydrogen occurs in one reactant (NaOH) and one product (H₂O). Na, S and O all appear in two products. Balance the equation in H atoms first:



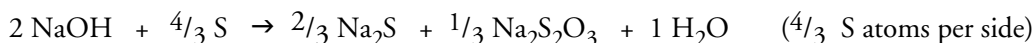
The next atom suitable for balancing is oxygen, as it is now present in only one unbalanced compound (Na₂S₂O₃):



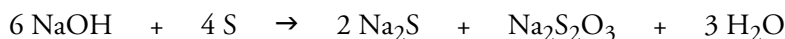
We can now balance the sodium atoms by adjusting the coefficients for Na₂S:



Finally, the sulfur atoms can be balanced:



Multiplying by 3 gives the balanced equation with the smallest whole-number coefficients:



Standard States of the Elements

- Most stable form of an element at 1 atm and 25°C
- Are the *reactants* in formation equations of substances
- The heat of formation (ΔH°_f) of an element in its standard state is *zero*

Standard States To Know

Gases		Liquids	
Hydrogen	H ₂ (g)	Bromine	Br ₂ (l)
Nitrogen	N ₂ (g)	Mercury	Hg(l)
Oxygen	O ₂ (g)		
Fluorine	F ₂ (g)	Molecular Solids	
Chlorine	Cl ₂ (g)	Phosphorus	P ₄ (s), white
		Sulfur	S ₈ (s), rhombic
		Iodine	I ₂ (s)
Solids (Non-Metal)			
Carbon	C(s), graphite	Silicon	Si(s)
Solids (Metal)			
Lithium	Li(s)	Magnesium	Mg(s)
Sodium	Na(s)	Calcium	Ca(s)
Potassium	K(s)	Aluminum	Al(s)
Iron	Fe(s)	Nickel	Ni(s)
Copper	Cu(s)	Zinc	Zn(s)
Silver	Ag(s)	Gold	Au(s)

Ground State Electron Configurations

Some important notes concerning ground state electron configurations of the elements:

- You will *not* be asked to provide the ground state electron configuration for an element with an atomic number greater than argon (Ar) on an exam or quiz. The regular pattern for ground state electron configurations is lost on going to elements with atomic numbers greater than argon because the energy gaps between the orbital subshells are very small for orbitals with $n \geq 4$. Therefore, the only way to reproduce the electron configurations for elements past argon (especially the transition elements) is to *memorize* them (which we don't want you to do).
- Electron configurations presented in the lecture or given on an exam or quiz will always be written so that the electrons are in order of *increasing* energy—the energy of the electrons in the configuration increases from left to right (see table below). The text gives electron configuration with a different ordering scheme (the “filling” order) that is of little practical use—it is more important to know the relative energies of the electrons in the atom.

**Condensed Ground State Electron Configurations of the Elements
(in order of increasing electron energy)**

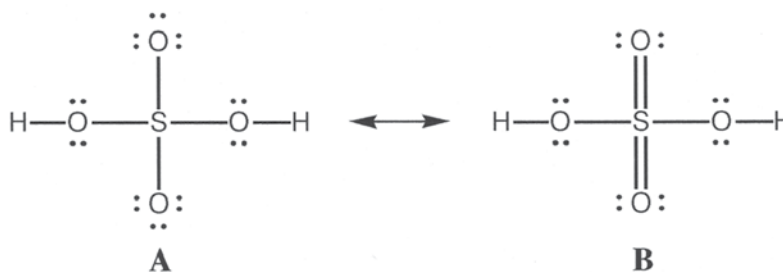
Element	Configuration	Element	Configuration	Element	Configuration
K	[Ar]4s ¹	Rb	[Kr]5s ¹	Cs	[Xe]6s ¹
Ca	[Ar]4s ²	Sr	[Kr]5s ²	Ba	[Xe]6s ²
Sc	[Ar]3d ¹ 4s ²	Y	[Kr]4d ¹ 5s ²	La	[Xe]5d ¹ 6s ²
Ti	[Ar]3d ² 4s ²	Zr	[Kr]4d ² 5s ²	Hf	[Xe]4f ¹⁴ 5d ² 6s ²
V	[Ar]3d ³ 4s ²	Nb	[Kr]4d ⁴ 5s ¹	Ta	[Xe]4f ¹⁴ 5d ³ 6s ²
Cr	[Ar]3d ⁵ 4s ¹	Mo	[Kr]4d ⁵ 5s ¹	W	[Xe]4f ¹⁴ 5d ⁴ 6s ²
Mn	[Ar]3d ⁵ 4s ²	Tc	[Kr]4d ⁶ 5s ¹	Re	[Xe]4f ¹⁴ 5d ⁵ 6s ²
Fe	[Ar]3d ⁶ 4s ²	Ru	[Kr]4d ⁷ 5s ¹	Os	[Xe]4f ¹⁴ 5d ⁶ 6s ²
Co	[Ar]3d ⁷ 4s ²	Rh	[Kr]4d ⁸ 5s ¹	Ir	[Xe]4f ¹⁴ 5d ⁷ 6s ²
Ni	[Ar]3d ⁸ 4s ²	Pd	[Kr]4d ¹⁰	Pt	[Xe]4f ¹⁴ 5d ⁹ 6s ¹
Cu	[Ar]3d ¹⁰ 4s ¹	Ag	[Kr]4d ¹⁰ 5s ¹	Au	[Xe]4f ¹⁴ 5d ¹⁰ 6s ¹
Zn	[Ar]3d ¹⁰ 4s ²	Cd	[Kr]4d ¹⁰ 5s ²	Hg	[Xe]4f ¹⁴ 5d ¹⁰ 6s ²
Ga	[Ar]3d ¹⁰ 4s ² 4p ¹	In	[Kr]4d ¹⁰ 5s ² 5p ¹	Tl	[Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ¹
Ge	[Ar]3d ¹⁰ 4s ² 4p ²	Sn	[Kr]4d ¹⁰ 5s ² 5p ²	Pb	[Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ²
As	[Ar]3d ¹⁰ 4s ² 4p ³	Sb	[Kr]4d ¹⁰ 5s ² 5p ³	Bi	[Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ³
Se	[Ar]3d ¹⁰ 4s ² 4p ⁴	Te	[Kr]4d ¹⁰ 5s ² 5p ⁴	Po	[Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ⁴
Br	[Ar]3d ¹⁰ 4s ² 4p ⁵	I	[Kr]4d ¹⁰ 5s ² 5p ⁵	At	[Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ⁵
Kr	[Ar]3d ¹⁰ 4s ² 4p ⁶	Xe	[Kr]4d ¹⁰ 5s ² 5p ⁶	Rn	[Xe]4f ¹⁴ 5d ¹⁰ 6s ² 6p ⁶

Note: The ground state electron configurations for Elements 1–18 given in the text are already given in order of increasing electron energy.

Expanded Octet Structures

Some important notes concerning “expanded octet” Lewis structures (Ch. 10 and 11 in the text):

- The need to “expand” the octet in Lewis structures for heavier main-group compounds such as PCl_5 and SF_6 is better thought of as a limitation associated with Lewis Theory rather than a case of the heavier main-group elements actually “expanding” their valence shells. This problem arises because Lewis theory *requires at least two electrons* for each bond, which is overly restrictive—it is possible for a main-group element to participate in more than four bonds while still having only eight valence electrons. More rigorous (and more complex) treatments of the bonding in these complexes can account for the ability of phosphorus to form five bonds in PCl_5 without violating the octet rule, but this material is beyond the scope of the course. The “expanded octet” Lewis formulas for compounds such as PCl_5 are *still useful*—especially when applying VSEPR theory to determine their shape—but they do not provide a very accurate picture of the chemical bonding for these compounds.
- You will be asked to determine the best or most significant resonance structure for a compound such as sulfuric acid (H_2SO_4), for which some resonance structures violate the octet rule and others do not. The text gives the following two resonance structures for sulfuric acid on page 367:



The text designates resonance structure **B** as the most important contributor to the resonance hybrid, because the sulfur and two oxygens have lower formal charges. However, resonance structure **B** violates the octet rule (12 electrons around sulfur), whereas structure **A** does not; it is therefore no longer obvious that structure **B** is the more important contributor to the resonance hybrid. Although formal charges can be used to judge the relative importance of resonance forms *when they all abide by the octet rule*, they should **not** be used in this manner for compounds with expanded octet resonance structures.

- We will not be covering sp^3d or sp^3d^2 hybridization in Chapter 11, for the simple reason that it is very unlikely that d -orbitals are directly involved in the bonding of a main-group compound. (They are too high in energy.) We will therefore only cover sp , sp^2 and sp^3 hybridization in this section. So then, how can you account for the bonding in compounds like PF_5 and SF_6 using valence bond theory? The best answer is that *you can't* (and so you won't have to).

Valence Shell Electron Pair Repulsion (VSEPR) Theory

What is VSEPR Theory?

- A powerful *empirical* method that can account for molecular shape—the relative position of the *atomic nuclei* in a molecule given its Lewis formula

The Primary Assumption:

- Molecules adopt shapes in which the valence electrons associated with an atom position themselves as far from each other as possible
- The molecular shape for the central atom(s) in a molecule is determined from the number and type of electron *groups*—single bonds, double bonds, triple bonds, and lone pairs—associated with the atom

Possible Electron-Group Arrangements:

# of electron groups	arrangement	ideal bond angle(s)
2	linear	180°
3	trigonal planar	120°
4	tetrahedral	109.5°
5	trigonal bipyramid	90° and 120°
6	octahedral	90°

Possible Molecular Shapes: see Ch10 and specifically Fig. 10.9 for more explanation.

# of electron groups	# of lone pairs	molecular shape	class
2	0	linear	AX ₂
3	0	trigonal planar	AX ₃
3	1	bent (v-shaped)	AX ₂ E
4	0	tetrahedral	AX ₄
4	1	trigonal pyramidal	AX ₃ E
4	2	bent (v-shaped)	AX ₂ E ₂
5	0	trigonal bipyramidal	AX ₅
5	1	seesaw	AX ₄ E
5	2	t-shaped	AX ₃ E ₂
5	3	linear	AX ₂ E ₃
6	0	octahedral	AX ₆
6	1	square pyramidal	AX ₅ E
6	2	square planar	AX ₄ E ₂

Distortions from Ideal Geometries With Different Electron Groups:

- Lone pairs will have a greater *repelling effect* than all bonding electron groups (lone pairs will act like they are *bigger* than bonding electron groups)
- The presence of lone pairs around a central atom will result in bond angles that are *smaller* than the ideal bond angles for that particular electron-pair arrangement (e.g. the H–O–H bond angle in H₂O is 104.5°, which is smaller than the ideal tetrahedral angle of 109.5°)
- Lone pairs will preferentially occupy the *least crowded* site in the molecule (e.g. the equatorial sites in a trigonal bipyramidal electron-pair arrangement)
- Multiple-bond electron groups (double and triple bonds) have a *greater* repelling effect than single-bond electron groups
- The presence of different types of bonding electron groups around a central atom can result in bond angles that are both *smaller* and *larger* than the ideal bond angles for that particular electron-pair arrangement (e.g. the H–C–O bond angle in H₂C=O is 122° and the H–C–H angle is 116°)

Important Reminder

- VSEPR theory says *nothing* about the nature of the bonding in compounds beyond that already established by a Lewis formula

Introduction to Professional Laboratory Work

LABORATORY NOTEBOOK

The laboratory notebook is critically important in industrial and research labs. All data and results obtained in the course of laboratory work must be recorded in the notebook. Because other workers may need the information from a coworker's notebook, the laboratory notebook remains in the lab at all times. In the CHEM 200 lab we hope to simulate this experience. This manual is your lab notebook, but instead of leaving the entire manual in the lab, you will tear out and leave only the notebook pages found at the end of each experiment.

You will use the laboratory pages for the appropriate experiment (starting with the Prelab Assignment) as your lab notebook for the day. The completed notebook pages will comprise your *lab report* for that experiment. Enter all information in the lab notebook pages in ink. The Prelabs are due at the beginning of the day the experiments are completed. The remaining parts of the lab reports are to be turned in at the end of the laboratory period. All the experiments are designed so that they can be completed during the laboratory period, but it is presumed that you have come *prepared*. Read the instructions for each experiment and complete the Prelab Assignment *before* coming to lab. Preparing your Prelab in advance will greatly improve your understanding of the subject material. If you have questions regarding the experiment, bring them to the helproom in advance.

Scientific Honesty and Integrity - Values and Ethics to Develop and Maintain Always

One of the most important parts of the course is learning the value of scientific honesty and integrity, and this means reporting your experimental values accurately. Human, random, instrument, and reagent errors are common and can distort known values for what may appear to be unusual measurements - discuss any unusual measurements with your TA and hopefully obvious discrepancies in your experimental measurements will have legitimate explanations. From time to time we discover inaccuracies in our reagents and/or instruments, and, of course, discovering mistakes in our own understanding, methods, techniques, and procedures is part of the "learning process". The world is not a perfect place, and unfortunately breaches in scientific ethics and scientific integrity have occurred at some of the highest levels of academia, government and industry. PLEASE become a leader, not a follower, in our scientific world by demonstrating honesty and ethical scientific values in every aspect of your work!

We cannot emphasize how important it is for you, as scientific professionals, to uphold honesty and scientific integrity here in the lab and wherever you go in your entire career. Your future workplace colleagues may or may not emphasize these values - we cannot stress how critical, fundamental, and important these values are in your daily academic life and your entire professional career. We urge YOU to bring to every person and to every workplace the values that we are encouraging you to maintain here at San Diego State University. Please uphold these standards of scientific honesty and integrity in ALL your work here in the laboratory, reporting your experimental values and measurements just as you read them - with honesty and integrity. Developing, maintaining, and upholding these values will make a long-term, fundamental, and critical difference in your entire scientific career, and most importantly in the world in which we all live. YOU are the future scientists, teachers, engineers, medical practitioners, and other career professionals of our world, and we are counting on YOU to bring quality, scientific honesty, and integrity to our SDSU labs and to our world! Scientific ethics begins and flourishes with YOU!

RULES FOR KEEPING THE LABORATORY NOTEBOOK

The laboratory notebook pages are found at the end of each experiment in the manual. Each experiment (except Experiment 1) contains a Prelab Assignment that should be filled out before starting the laboratory experiment. The Experimental Notes and Observations section of the laboratory notebook is used for the initial recording of measurements and observations during an experiment. The remaining pages of the notebook are for reporting the experimental data and results of each experiment. In some cases, tables for entering and organizing experimental data are given in the notebook pages; otherwise, you will construct your own data tables. (Remember, this can be done *before* coming to lab.) You can use both sides of the notebook pages; additional pages can be obtained, if necessary, from your TA. Any additional notebook pages must be titled and include your name and the date.

Use a pen, not pencil, to record your data. Record all experimental observations directly into the notebook pages at the time of the observation. Usually, the raw experimental data is recorded in the Experimental Notes and Observations section. Do not write information on other sheets of paper to transfer to the notebook pages later. Those sheets of paper could be lost or accidentally thrown away, and errors could be made when the information is later copied into the notebook.

YOUR MISTAKES MAY BE IMPORTANT! If you make a mistake anywhere in your lab notebook, draw a line neatly through the mistake; do *not* erase the error. If more than one line of text is involved, draw a diagonal line through the section that is incorrect. It is possible that something that you initially think is an error is actually correct. If you cross out the text, the information can still be read and used. In a research or development lab, this practice is also important for avoiding accusations of fraud. *Do not use correction fluid to cover errors in your lab notebook!* Note that you must turn in all notebook pages, even if the data on a page has been completely crossed out.

Some of the greatest discoveries in science occurred due to mistakes, accidents, and serendipity! If you have the “mistaken” data crossed out, you can easily go back to see your “mistake” – this is how penicillin was discovered – by Sir Alexander Fleming in 1928 – because he made a “mistake”:

Sir Alexander Fleming was a brilliant researcher, but a very careless lab technician. Cell cultures that he worked on he often forgot, and his lab benches were usually in chaos. After returning from a particularly long holiday, Fleming noticed that many of his culture dishes were contaminated with a fungus and so he threw the dishes into a disinfectant solution. But on one occasion, he had to show a visitor what he had been researching, and so he retrieved some of the unsubmerged dishes that he would have otherwise discarded. Upon pulling them out, he noticed a zone around an invading fungus where the bacteria did not seem to grow. Fleming proceeded to isolate an extract from the mould, correctly identifying it as being from the penicillium family, and therefore named the agent penicillin.

Your TA needs to be able to read your laboratory reports when grading them, so make every effort to be neat and orderly when writing in your lab notebook. This will be much easier to accomplish if you have adequately prepared for the experiment before coming to lab. Please show your TA what you can do by handing in complete and well-written lab reports! ASK YOUR TA if there is something that you do not understand. Also, we do not care if you work in committees with your fellow colleagues on your lab reports – because the most important part of your laboratory experience at SDSU is that you LEARN from your work in the lab! You can learn a LOT from your fellow colleagues in the lab solving problems with each other, and thus you can help each other if you wish. Students that create complete, accurate, and well-written lab reports score high on their labs and are a joy for the TA to grade! Work hard, learn well, collaborate with one another, and succeed!

ACHIEVING SUCCESS AND POINTS ON YOUR LAB REPORTS:

Here are some items you should keep in mind when you are working on your lab reports.

Significant Figures: You should *always* use the proper number of significant figures when taking a measurement or reporting the results of an experiment. For intermediate calculations, maintain at least one more significant figure than will be in the final value to avoid rounding errors. See Section 1.6 of the Silberberg text for a review of significant figures in measurements.

Prelab Assignment: Most experiments will have a Prelab Assignment that should be completed *before coming to lab*. This assignment will consist of questions and calculations that will help you prepare for the experiment. You will also be asked to identify any safety concerns associated with the experiment. Space for completing the Prelab Assignment is provided in your notebook.

Data and Results: It is often best to organize your experimental data and results into tables. If possible, prepare the data tables ahead of time if they are not included in the lab notebook. Each table should have a descriptive title and each column of the table should be labeled, including any units. Each line should also be labeled on the left hand side, usually with the number of the data point. If it is necessary to perform calculations using your experimental measurements, be sure to show your work in the Calculations section of the notebook. Only one sample calculation needs to be shown for each type of calculation performed; identical calculations for additional trials can be done on scratch paper. For example, if you need to calculate the density for three separate trials, calculations for only one trial need to be shown. Each sample calculation should include the following items:

- a descriptive name or title for the calculation
- a formula with no numbers included, just variables
- a formula with the numbers, data, or constants inserted
- an answer with correct units and significant figures

Discussion: Many of the experiments contain notebook pages for you to provide a discussion of your experimental observations and calculations. Write discussions in paragraph format with complete sentences. At a minimum, the discussion must include a statement of your results, a statement on what experimental results were expected, and a discussion of any systematic errors associated with your experimental data. You should comment on the accuracy and precision of your results (when applicable) and the usefulness of the experiment to the course.

Questions: Several experiments will have challenging questions for you to answer after you have completed all experimental work. Pages for answering these questions are provided in your notebook. You should never be uncertain of HOW to answer your questions – please ask your TA for help if these questions appear ambiguous or if they appear to be unreasonably challenging for you to answer. Many of these questions require significant time to answer. Please ask your TA for help or go to the Help Room, before your lab report is due so that you can achieve ALL points on your questions. PLEASE ASK YOUR TA FOR HELP so that you can achieve high scores on your lab reports! Additional pages, if necessary, can be stapled to your lab reports.

GENERAL LABORATORY RULES

Be considerate of the other students in your laboratory section and try to share the space and equipment in a safe and courteous way. Disturbances such as running, loud noises, and practical jokes can lead to serious accidents and must be avoided. Any student who refuses to comply with requests from a TA or who is repeatedly involved in improper lab conduct will be asked to leave the laboratory and will not be allowed to finish lab work for that experiment. Continued and repeated violations of laboratory rules may result in expulsion from the course.

Do not begin laboratory work if other students are still taking quizzes or if your TA has not finished lecturing. Also, please be aware of those around you so that you will be prepared if an accident happens. PLEASE notify your TA immediately if there is an accident or broken glass! **ALSO, YOU SHOULD ALWAYS WEAR YOUR SAFETY GOGGLES IN LAB DURING EACH AND EVERY LABORATORY EXPERIMENT DAY**, regardless of what procedures you are currently performing—someone near you may be doing something hazardous even though you have finished with your own experiment.

PLEASE CLEAN UP YOUR LAB BENCHES WHEN YOU HAVE FINISHED WITH YOUR WORK. You must leave the laboratory in as good condition as when lab started. This includes returning all supplies to their proper place and cleaning all areas in which you worked. You may lose points on your laboratory report if you do not leave your laboratory space clean.

Waste chemicals must be disposed of properly. For most of the experiments there will be special containers for the various materials, and your lab instructor will tell you the proper way to dispose of each waste. *Never pour potentially toxic waste down the drain!* If you are uncertain if something is safe to pour down the drain, PLEASE ask your TA.

SAFETY

You *must* follow good safety practices while in the laboratory in order to prevent accidents. Our department has a very good laboratory safety record—it is extremely unlikely that there will be a serious accident if you learn and follow some simple precautions. These rules are for YOUR SAFETY!

- *You must wear approved safety goggles* that have protection from all directions and protective wear whenever *anyone* is doing laboratory work in the room. ABSOLUTELY NO EXCEPTIONS TO THIS RULE! This is by far the most important safety precaution that you can take in ANY laboratory environment. Almost any injury to the body that could happen in the laboratory will heal—with the possible exception of eye injuries. Your eyes are absolutely irreplaceable and priceless: YOU NEED TO PROTECT THEM AT ALL TIMES!
- Before you are allowed to do any laboratory work, you will have to pass a laboratory safety quiz. It will be on-line and available for you to complete from home.

- *You must wear shoes with closed toes* in the laboratory at all times. Frequently there will be broken glass on the floor, and chemicals that are spilled on the floor can be absorbed through the skin. If you elect to wear sandals or other open-toed shoes during the rest of your day, then PLEASE PLAN TO LEAVE A PAIR OF CLOSED-TOED SHOES IN YOUR LAB LOCKER TO USE DURING YOUR LAB EXPERIMENTS! You will be asked to leave the lab if you do not comply with this rule.
- You will need an approved laboratory coat or apron to work in the labs. This coat or apron provides an important layer of protection in the case of a chemical spill. Long hair should be secured (tied back or pinned up) and your hair and/or jewelry should never dangle onto the lab benches and experimental areas. The lab coat or apron should fit and not be too large. (The lab aprons can be adjusted).
- Learn in advance the location of fire extinguishers, safety showers, eyewash fountains, and other emergency equipment so that they may be used quickly when needed. Your TA will point out the location of these items.
- *Never taste any chemical in the laboratory.* Use a rubber bulb to draw liquid into a pipet. You should never eat or drink while in the lab—food may easily become contaminated.
- **ALWAYS WASH YOUR HANDS AND YOUR ARMS THOROUGHLY AFTER YOU FINISH YOUR LAB WORK.** It is possible for you to get chemicals on your hands without realizing it. Wash your hands before you touch your face to avoid getting chemicals in your eyes or mouth.
- Move carefully and deliberately in the lab; avoid bumping anyone. This is especially important when you are carrying chemicals or glassware to and from the stockroom. Students with disabilities that might make it difficult for them to handle chemicals and equipment safely must consult the course coordinator before laboratory work begins.

FIRST AID

- If you get chemicals in your eyes, *immediately* wash them with a large amount of water. The eyelids should be pulled back while the eye is thoroughly washed with water. An eyewash fountain is available in every laboratory. Someone else should notify the TA of the accident IMMEDIATELY.
- Many chemicals will injure or burn the skin. Also, many chemicals can be absorbed into the body through the skin. If you get significant amounts of any chemical on your body or clothes, wash with large amounts of soap and water and notify your TA.
- If your clothes begin to burn, remove burning clothing *immediately* OR *immediately* roll on the floor to try to extinguish the flames. Other students should help by patting the area with their hands and by wrapping a fire blanket (or jacket, etc.) tightly around the burning area. As soon as the flames are extinguished, use water to quickly cool the skin to minimize the injury. PLEASE ALWAYS USE ICE ON ANY AREA OF SKIN THAT HAS BEEN BURNED – WITH CHEMICALS OR WITH FLAMES!
- Report all injuries (cuts, burns, etc.), no matter how minor, to your TA immediately. A safety report must be filled out for every accident or safety incident.

Using Analytical Balances

The modern electronic balances in your lab are precision analytical instruments that need to be handled with care to function properly. The sample is placed upon a metal balance pan located inside glass or clear plastic enclosure. The mass (weight) can be read from the digital display on the front panel. The balances are readable to 0.001 grams.

IMPORTANT REMINDERS

1. The balances are set on a stable and level bench and should not be jarred or moved. Do not place objects directly on any part of the balance.
2. Do not place chemicals or unknown objects directly on the balance pan. Always place your sample in a clean container, or on a watch glass or a piece of paper.
3. Do not transfer chemicals to or from a container while it is directly on the balance—this will lead to chemical spills that can seriously damage the balance. If you do spill chemicals onto the balance, immediately clean it up and notify your instructor so that the balance pan and surrounding area can be cleaned.
4. Do not drop things onto the balance pan or place unreasonably heavy items on the balance. The balances can measure masses up to approximately 300 grams. These actions can cause permanent damage to the balance mechanism.

II. Operating the Analytical Balance

1. The panel on the front of the balance contains a display and five pushbuttons below the display. The buttons, from left to right, are: (1) ON/OFF, (2) Tare, (3) changing units, and (4) and (5) for calibration purposes. We will use only the two leftmost buttons to weigh samples. If the display is blank, press the button to the far left to turn on the balance. Be sure the pan is empty when it is turned on. Do not turn the balance off until the labs are over.
2. The balances are adversely affected by moving air from ventilation systems hitting the balance pan. Some of the shields have four sides, whereas others have a fifth side (top) above the balance pan. If your balance has one, lift the top using the handle to place samples on the balance for weighing. Ask your instructor for assistance if you are uncertain how to do this.
3. **Taring the balance:** This method works well if you stay at the balance while making the measurements. Place an empty sample container on the balance pan, close the draft shield door, if present, and press the tare button (marked as O/T). The balance is tared when the display reads 0.000 g. Remove the sample container and proceed to adding sample to the container.
4. **Sample Weight Using Tare:** Tare the balance as described in the previous paragraph. Remove the sample container and do not tare the balance until you are finished adding sample. When you have put the sample in the container, return it to the balance and record the weight. The balance should now display the mass of the object or sample without the weight of the sample container. Repeat this procedure if you need to add more to your sample.

5. **Direct Weighing:** If you are not going to weigh a sample immediately after taring the balance, then you must record the actual weights of the sample container and the sample plus container. This is because while you are away from the balance, another person may use the balance and reset the tare the balance for their own sample. Every time you record the direct weight of a sample, you must first tare the balance so that it reads 0.000 g, before adding any sample or container. When you return with the sample, tare the balance first, then record the weight of sample plus container. To obtain the sample weight, subtract the weight of the container from the weight of the sample plus container.
6. **Weighing by Difference:** It is also possible to weigh a sample by measuring the amount of sample removed from a container. Place a container plus sample on the balance and tare the balance. Take the container off of the balance pan and then remove some of the sample, being careful not to spill any. Place the container back on the balance and it will display the amount of the sample removed as a negative mass.

TROUBLESHOOTING

- A blank display most likely means that the balance is not turned on or plugged in.
- Flashing zeros indicates that the unit is unable to zero. Notify your TA if this occurs.
- | - - - - | is overload—the mass of the object on the balance exceeds the maximum allowable for that balance.
- | - - - - | is underload. Press the control bar to reset the balance. If that doesn't work, notify your TA.
- -OFF- indicates that there has been a power loss. Press the control bar to turn the balance back on.
- A small circle on the left of the balance display indicates that the current mass reading is unstable. Notify your TA if this occurs.
- -Err- or -Error- indicates that some type of error has occurred with the balance. Try pressing the control bar to reset the balance. If that doesn't work, unplug the balance, wait a few seconds, and then plug it in again. If the error message is still there when you turn on the balance, notify your TA.

Error Analysis

INTRODUCTION

Most measurements are neither exact nor precise. Exceptions include exact counts (*e.g.* the number of students in a room) and numbers which are exact by definition (the speed of light is defined as exactly equal to 299,792,458 m/s). Some numbers (such as π) can be calculated to as many significant figures as we wish, and many conversion factors (such as 1000 mL/L) are also exact. However, almost all numbers with which you will work are uncertain to some extent.

ERRORS IN MEASUREMENT

For any quantitative measurement, there is a correct or “true” value. We expect that any measured values reported in the literature are “true” values and when the measurements are reproduced in more than one laboratory, we become even more confident of the accuracy of that measurement. If we know the “true” value, we can report our *error* as:

$$\text{error} = (\text{measured value}) - (\text{“true” value})$$

Other quantities which are sometimes reported are the *relative error*, which is the error divided by the measured value, and the *percent error*, which is the relative error expressed as a percentage (multiplied by 100).

If we make one measurement and find that the error is significant, we would say that there is a discrepancy between our result and the literature value and such a discrepancy could be caused by a number of reasons:

- 1) You are a novice and you made some mistakes in the measurement or the analysis.
- 2) Your apparatus is not calibrated correctly and there is *systematic error* resulting from this.
- 3) The “true” value is actually incorrect!
- 4) The error is a random fluctuation.

If the first point applies to you, checking both the procedure and calculations is important. In fact, even experienced scientists can make mistakes and know that they have to continuously check their work.

The second point can be corrected by assuring that your instrument is well calibrated. This involves making a measurement on a standard sample, that is, a sample for which very careful and reproducible measurements have been made. An experiment which shows how systematic error in density measurements can be reduced through calibration of volumetric glassware is included in this manual.

It is always possible that the “true” value is incorrect and if you are very confident that you have not made any mistakes and your instruments are properly calibrated, point 3 should be considered as a possibility. Scientists sometimes disagree in their results and, if the measurement is very important, a controversy will eventually right itself by reevaluation of the results by many people.

The fourth possibility for error, random fluctuations in the environment (such as temperature fluctuations or vibrations), can be reduced by developing higher quality instruments and being more careful, but, ultimately, *random error* will always exist to some extent. The best method for reducing any residual random error is to take multiple measurements; if the error is truly random, the set of measurements will deviate randomly around the “true” value. Then, the average will be the best estimate of that value and the more measurements that are done, the closer the average will be to the “true value” (assuming no systematic error). The range of values obtained with several measurements is used to estimate the uncertainty of the result and this range can be mathematically expressed by one value, the standard deviation, σ . The standard deviation is given by the following equation:

$$\sigma = \sqrt{\frac{\sum_i (x_i - \bar{x})^2}{n - 1}} \quad \text{where } \bar{x} = \frac{\sum_i x_i}{n}$$

x_i is the value of a particular measurement and \bar{x} is the average of n measurements. To use the equation for σ , first calculate the average and then subtract the average from the value of each measurement.

Fortunately, most calculators are able to calculate the average and standard deviation of a set of numbers with a function key. Try out your calculator with these measured values for the melting point of naphthalene: 80.6 °C, 80.7 °C, 81.2 °C. You should determine that $\bar{x} = 80.8$ °C and $\sigma = 0.3$ °C.

The final result would be written as 80.8 ± 0.3 °C. This means that

we are very confident that the “true” value is between 80.5 °C and 81.1 °C. The mean (with the bar on top of it) is the sum of: (80.6 + 80.7 + 81.2) divided by THREE, which equals 80.8. Since we only have 3 sample numbers (80.6 , 80.7, and 81.2), therefore $n = 3$. Sigma (σ) is the Greek symbol for standard deviation, so your equation would look like this:

STEP 1: $\sigma =$ the square root of all of the following: [(80.6 – 80.8)² + (80.7 – 80.8)² + (81.2 – 80.8)²] divided by $n-1$ (which is $3-1 = 2$).

STEP 2: $\sigma =$ the square root of all of the following: [(0.2)² + (0.1)² + (0.4)²] divided by 2

STEP 3: $\sigma =$ the square root of all of the following: [(0.04) + (0.01) + (0.16)] divided by 2

STEP 4: $\sigma =$ the square root of all of the following: [(0.21) divided by 2]

STEP 5: $\sigma =$ the square root of the following: 0.105 = 0.324 = **0.3** when rounded off to 1 significant figure right of the decimal point.

If there is no “true” value available with which to compare our results, our work constitutes a new contribution to science. Before it is published we want to assure that all errors are reduced as much as possible. Experience gained in trying to reduce errors on known samples is critical to this process.

ESTIMATING UNCERTAINTY FROM SINGLE MEASUREMENTS

When the number of interest is the result of a simple measurement, such as the temperature using a mercury thermometer, the uncertainty can often be estimated satisfactorily by how easily the instrument can be read. Suppose that the marks on the thermometer are one degree apart. It is almost always possible to estimate the temperature to better than ± 1 °C because you can estimate what fraction of mercury is between the two nearest marks. This method is called INTERPOLATION: estimating a number to a precision not shown by the division marks on the thermometer. If the marks are widely spaced, then you may be able to reliably estimate the temperature to within ± 0.1 degree, but if the marks are very closely spaced, you may be able to only estimate the temperature to within ± 0.5 degrees. This requires judgment and experience, and you are not expected to estimate the uncertainty of a measurement the same as the instructor (or anyone else!) would.

CALCULATIONS

Suppose that you need to do a calculation that involves two or more numbers, each of which has some uncertainty. How do the individual uncertainties affect the calculation?

Take the example of calculating the pressure of a gas from the measurement of its volume and temperature, assuming that the number of moles of gas is known exactly. The uncertainties in the temperature and volume were estimated during the experiment.

$$p = nRT/V; \quad T = 300.0 \pm 0.8 \text{ K}; \quad V = 20.00 \pm 0.06 \text{ L}; \quad n = 1.000 \pm 0.000 \\ R = 0.0820578 \text{ L atm K}^{-1}\text{mol}^{-1}$$

The constant R is an accurately measured literature value and we assume that the error is negligible. The best estimate of the pressure is $p = (1.000) (0.0820578) (300.0) \div (20.00) = 1.231$ atm.

The rules for determining the number of significant digits were used to limit the result to four significant digits. Reporting the number in this way suggests that the uncertainty in the result is ± 0.001 atm. In the following calculations, we will show that even though this method is simplistic, it does give a good estimate of the uncertainty.

Let's look at the affect of the uncertainty in the temperature, reported as ± 0.8 K, on the final pressure. First, calculate the pressure again with a temperature of 300.8 K, which is the highest value that we think the temperature could have been during the experiment.

$$p = (1.000) (0.0820578) (300.8) \div (20.00) = 1.234 \text{ atm}$$

The pressure differs from the original calculation by $|1.231 - 1.234| = 0.003$ atm. Since the uncertainty in the temperature can also affect the pressure in the other direction (the lowest value that we think the temperature could be is 299.2 K), the effect of the uncertainty in the temperature on the uncertainty in the pressure would be ± 0.003 atm.

Similarly, we can calculate the pressure with the highest and lowest values that we think the volume could have been, 20.06 L and 19.94 L, respectively. From this, we find that the effect of the uncertainty in the volume on the uncertainty in the pressure would be ± 0.004 atm.

The sum of the uncertainties to the pressure caused by both effects could be used to estimate the uncertainty: $p = 1.231 \pm (0.003 + 0.004) = 1.231 \pm 0.007$ atm. This is not a bad estimate when there are only two variables with uncertainty. However, the sum always overestimates the uncertainty since errors from both the temperature and the volume are not likely to occur as the maximum in the same direction. A better estimate of the uncertainty in the pressure is given by using the square root of the sum of squares of each error: $[(0.003)^2 + (0.004)^2]^{1/2} = 0.005$ atm. Therefore, we should report our result as $p = 1.231 \pm 0.005$ K. Although 0.005 is larger than the uncertainty suggested by the number of significant digits in the result, it is the right order of magnitude, so taking care of significant digits is a good way to estimate the uncertainty in the result of a calculation.

GRAPHING LABORATORY DATA

The value of laboratory data depends not only on their accuracy, but also on their organization into patterns that make them meaningful. Graphs are pictorial representations of data that are especially helpful in revealing a pattern of behavior and deviations from that pattern by experimental measurements that are in error. The most easily interpreted behaviors are those that fit a straight line because deviations are easily seen.

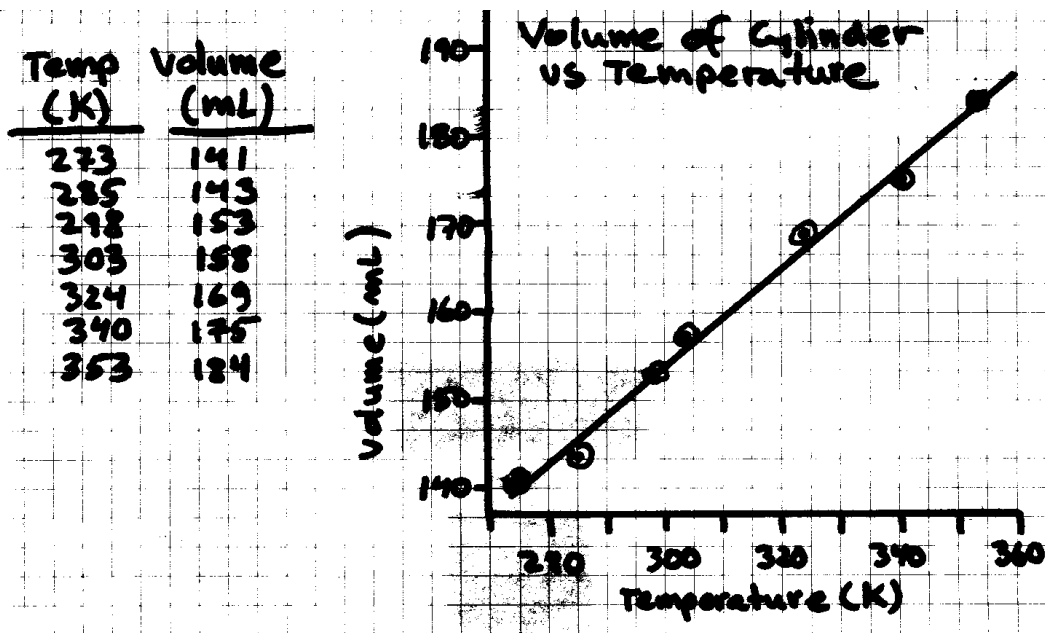
The character and construction of the straight line graph can be seen from the following laboratory data collected to test Charles Law for gases. Data collected in a laboratory notebook by a student to verify this law is shown on the next page. Charles Law states:

At constant pressure, the volume occupied by a fixed amount of gas is directly proportional to the absolute temperature of the gas.

$$V = k T$$

Note the following points about the data entries and the FORM of the graph (next page):

1. The Data is presented in tabular form.
2. The data is plotted with the dependent variable (volume) on the y-axis and the independent variable (temperature) on the x-axis. Both axes are labeled with the proper units of measurement.
3. The graph has a descriptive title.
4. The scale divisions on both axes have been chosen to span all of the data and to spread the data out over the entire space set aside for the graph.
5. A line was drawn through all the data points that minimizes the deviations, if any, from the line. This line represents the “best fit” line to the experimental data.



PLEASE NOTE: WHEN MAKING A GRAPH OF YOUR DATA, IN ALL INSTANCES YOU MUST PUT YOUR UNITS OF MEASURE ON EACH AXIS! For instance, if you have “TEMPERATURE” on the X-axis, and the “TEMPERATURE” is in the “KELVIN” unit of measure, then the temperature appears as: “Temperature (K)” as a label on this X axis, or you could write instead “Temperature (Kelvin)”, just as it appears in the example on the previous page. On the Y-axis your label should read “Volume (mL)” or you could write “Volume (milliliters)”. YOU MUST ALWAYS PUT A “DESCRIPTIVE TITLE” ON YOUR GRAPHS throughout your entire scientific career - please remember to do this!

The slope of a line is given by the general equation $y = m x + b$, where m is the slope and the constant b is the y-intercept. In this graph, y is volume (V), and x is temperature (in Kelvin). The slope (m) of the line is derived by the change (Δ) in the y value divided by the change (Δ) in the x value, usually written as $\Delta y / \Delta x$. From the graph, we can read the value of y at two temperatures. The values of y at 300 K and 340 K are 155 and 177 mL, respectively, and the slope can be calculated to be:

$$\Delta y / \Delta x = (177-155) \text{ mL} / (340. - 300.) \text{ K} = 0.550 \text{ mL/K}$$

PLEASE REMEMBER THAT THE DELTA SYMBOL (Δ) MEANS “CHANGE”. “ ΔT ” means the “change in temperature”, thus you must subtract one temperature value from a second temperature value in order to get a “change” (Δ) in temperature. The intercept b can be calculated as from rearranging the general equation and solving for one value of y (say 340 K):

$$b = y - (m \cdot x) = 177 - (0.550) (340) = - 10. \text{ mL}$$

We arrive at a final equation defining the linear relationship in the graph as:

$$y \text{ (mL)} = 0.550 \text{ mL/K} \cdot (\text{K}) + (-10. \text{ mL})$$

This equation can be used to calculate the expected volume at any temperature. Thus at the standard temperature (273 K or 0 C) the volume would be:

$$V \text{ (mL)} = (0.550 \text{ mL/K}) (273 \text{ K}) - (10. \text{ mL}) = 140. \text{ mL}$$

